

TECHNIQUES FOR MAGNETIC FIELD MONITOR OF THE LOW FREQUENCY TRAPEZOIDAL PULSE MAGNET WITH THE NMR

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Abstract

Measurement of magnetic field of the lattice bending magnet is important to control the beam orbit, tune control and the timing of the fixed magnetic field. Hole probe and search coil are used conventionally and NMR has been considered to know the only DC magnetic field. Authors have developed the technique for the magnetic field monitor of the pulsed magnet such as the main ring magnet of the 12GeV KEK-PS. During the injection (550 ms) and flat top (1-2 s) periods, magnetic field is measured by NMR probes with the frequency scanning. If we want the timing pulse at any magnetic field during acceleration, NMR probe can measure it with a fixed frequency mode. It depends on the principle of the NMR, which occur the nuclear magnetic resonance in the relation between the quantum axis magnetic field and the frequency of the rotational magnetic field in the perpendicular plane. The performance of the technique for the magnetic field monitor by NMR and some unique results of the magnetic field in the lattice bending magnet will be presented.

1 INTRODUCTION

Magnetic-field measurement by nuclear magnetic resonance (NMR) has been very well described. This is known as the Larmor frequency, is directly proportional to the magnetic field, H , and it's angular velocity is given by

$$\omega_0 = \gamma H,$$

where γ is the gyromagnetic ratio. The field is measured by exciting the resonance with an rf oscillator and measuring the frequency at which energy is either absorbed by the sample (resonance absorption).

1) As a case of the low frequency trapezoidal pulse magnetic field, such as a hadron synchrotron, NMR method can be applied during a beam injection and a flat top period.

2) NMR occurs when an oscillating field equal to the frequency of the Larmor frequency. Then, even if during accelerating period, when the bending field become to the fixed rf frequency NMR will occur.

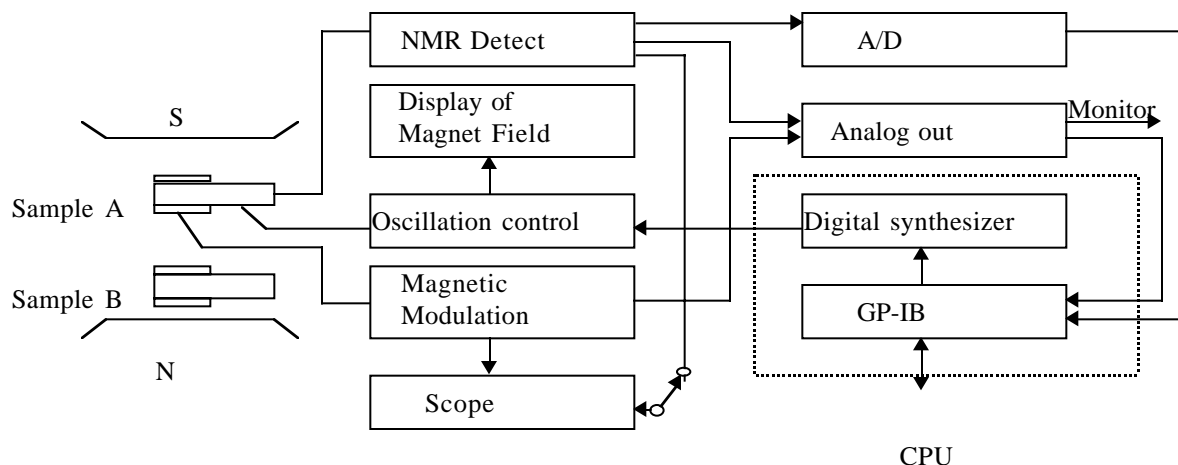


Figure 1 : Block diagram of the NMR measurement system.

Resonance absorption sample is a solid proton, then the resonance frequency is 42.567 MHz/T.

Specification of this system is as follows [1];

- Measurement Field Range: 0.14 T - 1.7 T
- Resolution: 2×10^{-5}
- Sample: Solid Proton
- Frequency Stability: $1 \times 10^{-5}/\text{min}$.
- SCOPE-Y: 1V (p-p)
- SCOPE-X: 5V (p-p)
- Dimension of Probe: $15 \times 20 \times 30 \text{ mm}$.
- Uniformity: $1 \times 10^{-4}/\text{cc}$

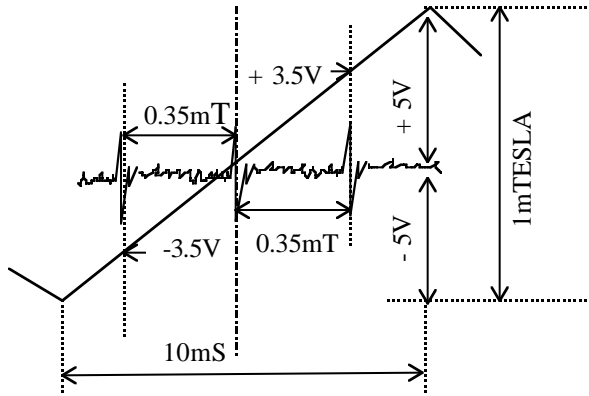


Figure 2 : Conception of the NMR measurement system.

2 CONCEPTION OF THE MEASUREMENT SYSTEM

2.1 Measurement of the Injection and the Flat Top Period

Figure 1 shows a block diagram of the NMR measurement system. The resonance frequency is divided two at a fixed magnetic field of an injection and a flat top period. Then, two absorption samples (A and B in Figure 1) are set in the magnet gap. According to the strength of the magnetic field, the frequency which can be obtained the NMR absorption signal should be set. The magnetic field can be measured with a range of $\pm 5\text{G}$ around the set frequency. Frequency is scanning by the time of 10 ms and following 10ms is the initializing time, then the measurement can be done in every 20 ms. Out-put signal level is 1G/V, that is full scale is 10 V. Two resonance absorption samples were set for the injection field and the flat top field, respectively. For the flat top measurement, the scanning frequency is provided to four range, a : 0.11 - 0.25 T, b : 0.25 - 0.5 T, c : 0.5 - 1.06 T and d : 1.06 - 1.8 T, to meet the variable flat top energy.

Conception of the measurement principle is shown in Figure 2.

2.2 Measurement of the Gradient Field (in Time)

Slow rise time magnetic field such as a synchrotron magnet can be measured by NMR. As more detail, one can recognize when the magnetic field comes to the value of resonance absorption at a fixed frequency oscillation field. This phenomena likes that which is well known as the spin depolarizing resonance during acceleration [2]. As a case of KEK 12 GeV-PS, the main bending magnetic field rises about 2T/s. We can know the time from an acceleration start to when NMR occurs. Range of the magnetic field is too wide, 0.14 T - 1.7 T for this case, to measure by one absorption sample, then four samples cover each four ranges, A: 0.15 - 0.25 T, B: 0.25 - 0.5 T, C: 0.5 - 0.98 T and D: 0.98 - 1.7 T. Figure 3 shows a measurement results of the 12 GeV operation. Horizontal axis is a time from acceleration start and vertical axis is the magnetic field. Fig. 4 shows a time fluctuation for ten minutes at a set of RF frequency for 1 tesla. Fluctuation is about 400 μs full width. It is considered that this fluctuation caused from the line fluctuation of the main ring power supply.

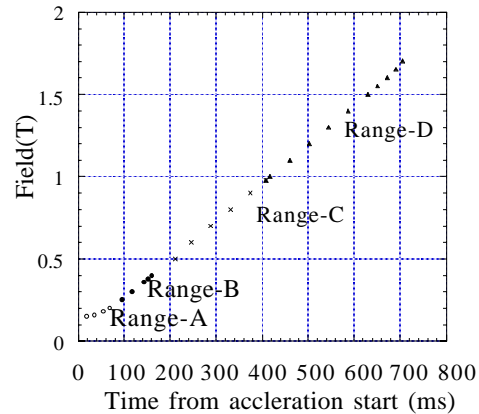


Figure 3 : Magnetic field measurement using NMR during acceleration.

3 CONCLUSION

At this present, several tools are set of measure the main bending magnetic field in the gap, a hall probe to measure the injection field and the gauss meter to monitor the magnetic pattern[3] and the NMR measuring system described above. As a result of using the NMR measuring system, we become to know the new information, that is, the dynamic phenomena of the magnetic field such as time delay of magnetizing depends on the time-length of the flat top and/or the current of the flat top. For example, a delay of the magnetic field at the beginning of the flat top field is shown in Figure 5. From the fitting functions, there are two component of the time constant, 70 ms and 660

ms. When the magnetic field of the flat top is low, there is one time constant of 70 ms. This phenomena is still in investigation, but it is considered the magnetic viscosity. As a measurement of the time from an acceleration start to the fixed magnetic field, this can be applied to the timing pulse in stead of the conventional gauss clock when we need the timing during acceleration, such as a transition crossing.

4 ACKNOWLEDGMENTS

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5 REFERENCES

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- [2] H. Sato et al., Nucl. Instrum. & Methods A 272 (1988) 617
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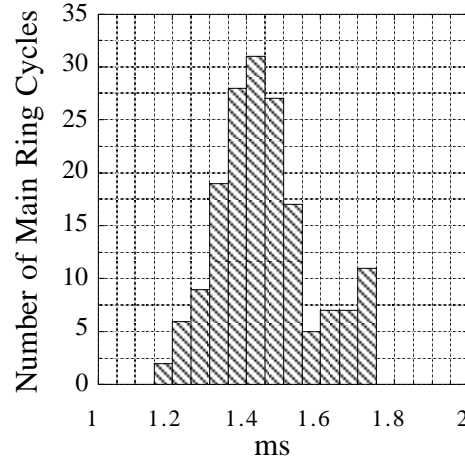


Figure 4 : Fluctuation of the time from acceleration start to 1 tesla for about ten minutes.

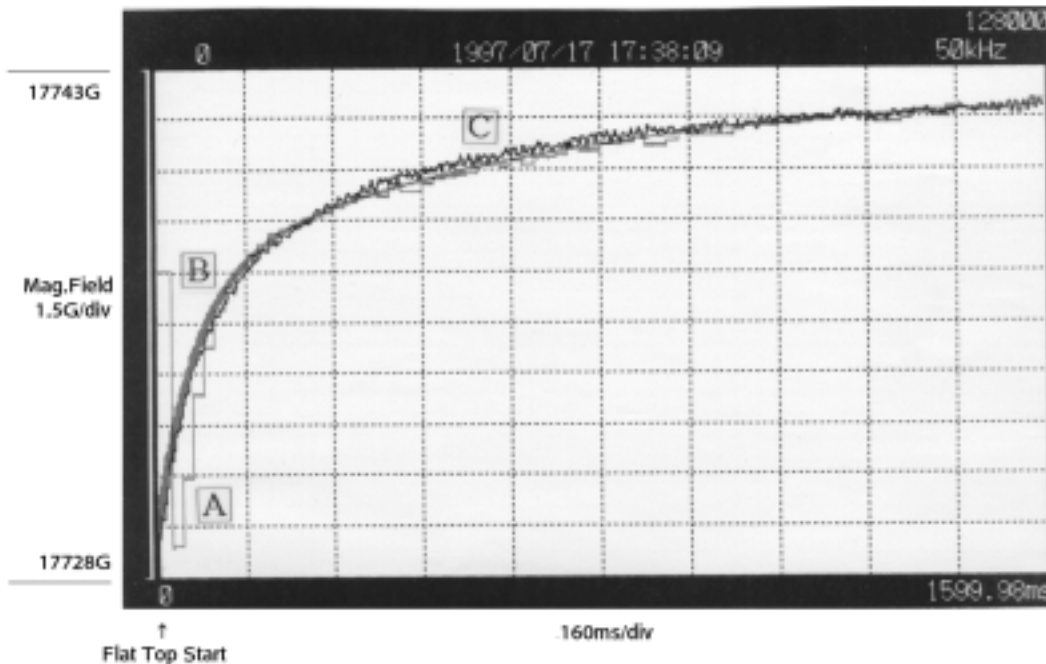


Figure 5 : Example of the time delay of the magnetization. Flat top start means the end of acceleration, 2T/sec, and the field comes to constant of 1.77 T.

A : NMR measurement. B : Fitting function. $f = 17742.4 - 7 \times e^{-t/0.07} - 5.5 \times e^{-t/0.66}$

C : Backleg winding measurement to check the systematic error.